Application Brief

Fold Back Current Limiting on User Ports of Smart Meters

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Introduction

The advent of smart electricity meters brought standardized advanced metering infrastructure (AMI) to facilitate basic requirements for installation, metering, maintenance, privacy, and security. As shown in Figure 1, the AMI has five communication ports P_0-P_4, of which ports P_1 and P_3 are critical.

Port P1 (also called *user port*) provides interface with the end consumer and is designed for in-house communication to provide real-time data for further analysis via Other Services Module (OSM) such as in-home displays. P1 is a read-only interface. Port P3 supports two-way communication and acts as interface to an external communications module.

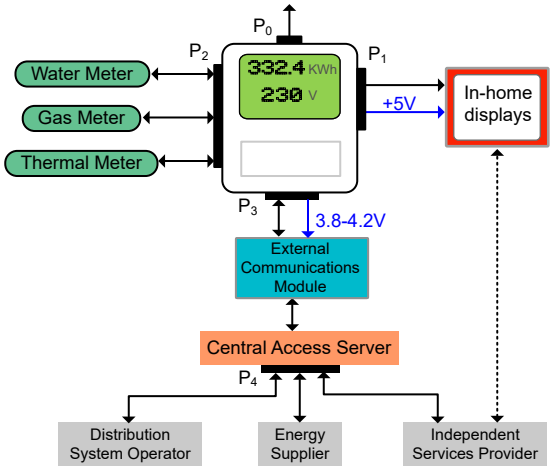

Figure 1. Illustration of Smart Metering Infrastructure

The ports P_1 and P_3 includes both power and data lines, and should be designed in such a way that they do not interfere with the metrology of the electricity meter under any external faults. These two ports should comply to safety protection requirements as per IEC 60747-5-5, and Dutch P1 Companion standards. eFuses in Smart Electricity Meters Application Brief highlights how the protection functions of TI eFuse and power MUX devices safeguard Port P_3 of the electricity meter from an external communication module malfunction or faults. This article addresses the protection solution for the user port P_1.

Port P1 Protection Requirements

The port P_1 provides galvanically isolated power to OSM on +5 V rail with maximum continuous current I_{L_CONT} of 250 mA. The protection requirements on +5 V power supply line at port P_1 side are

- Overload protection should trigger for currents above I_{L_CONT} + 10 mA (for example, 260 mA) but within I_{L_MAX} <=30 0mA
- Short-circuit protection
- Overvoltage protection from external overvoltage > 5.9 V, caused by or a failure at OSM side or by an incorrect connection. Similarly, OSM device should be protected from an overvoltage caused by a failure at metering system side, and should limit the voltages to less than 15 V.
- For sustained overload or short-circuit faults, current should fold back to maximum of 50 mA to reduce system operating temperatures and to avoid any harmful effects. The fold back current profile is illustrated in Figure 2

Implementing all these protection features could result in a large discrete circuit. In addition, realizing the foldback current limiting can be tricky to implement as it needs a means to detect overload and then adjust the current limit reference. All these discretes occupies significant board space and could not be possible to accommodate in a space constraint smart meter.

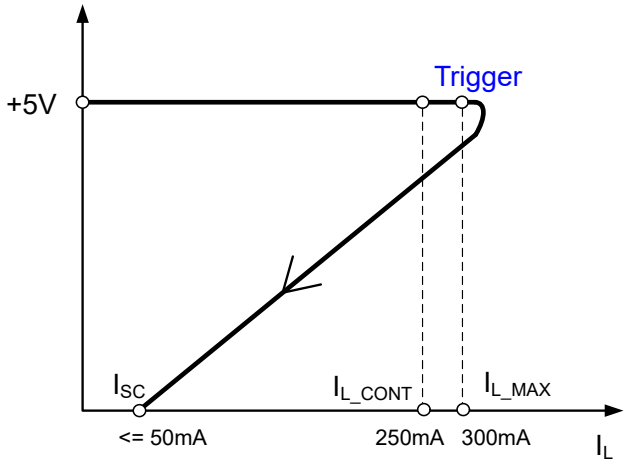

Figure 2. Fold Back Current Limiting Characteristics

Solution with TPS2662 eFuse

To meet all of the protection requirements for port P1, an eFuse such as the TPS2662, can be used. It offers a current limit which can be adjustable from 25 mA to 880 mA, reverse current blocking and programmable overvoltage protection. Figure 3 shows the application schematic circuit of TPS2662 eFuse positioned on the +5 V power supply rail path for port P_1 protection.

- The overvoltage protection (set at OVP pin of TPS2662) helps to protect OSM against overvoltages from the metering system side
- The integrated reverse current blocking feature of TPS2662 helps to block the external overvoltages from port P_1 (for example, OSM side) reaching +5 V power supply
- The overload current limit I_{OL} can be set by the current limit resistor R_{ILIM} at the ILIM pin using the expression I_{OL} = 6.636 / R_{ILIM}. This also sets short-circuit protection threshold at 1.6x I_{OL}

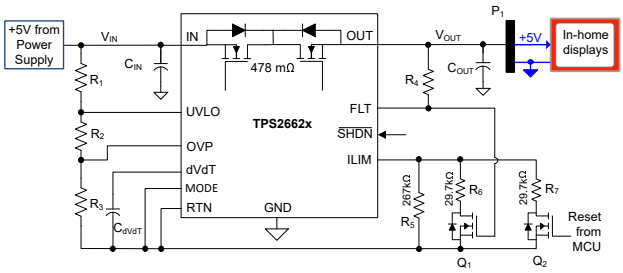

Figure 3. Application Schematic of TPS2662 eFuse with Fold Back Current Limiting

To implement the fold back current limit function, different ILIM resistors can be used to fold back the current to a lower level. External mosfets can be used to switch these different resistors as shown in Figure 3 and described in the following:

- In steady-state operation, the $\overline{FLT}$ output of TPS2662 stays HIGH. This sets current limit value corresponding to the current limit resistance of R_5 || R_6 for example, 260 mA.
- During fault, the $\overline{FLT}$ asserts LOW and the current limit gets reduced to 25 mA corresponding to current limit resistor R_5.
- Current limit resistor R_7 helps to set higher current during startup to support load startup load.

Test Results

Figure 4 and Figure 5 shows the fold back current limiting behavior of TPS2662 for overload and short-circuit events. As shown, the current is limited to 25 mA for sustained faults at the port P_1.

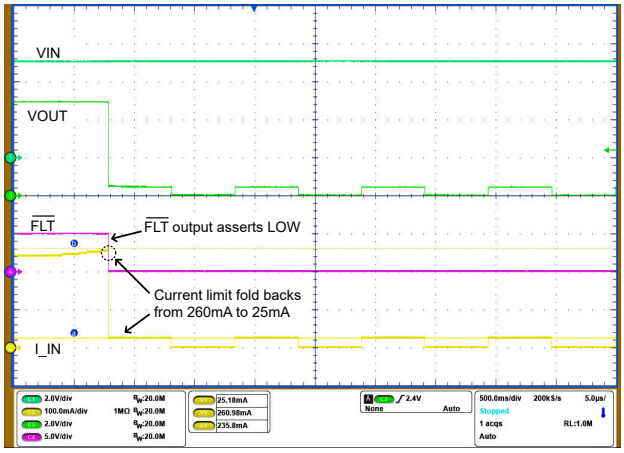

Figure 4. Fold Back Current Response during Overload Event

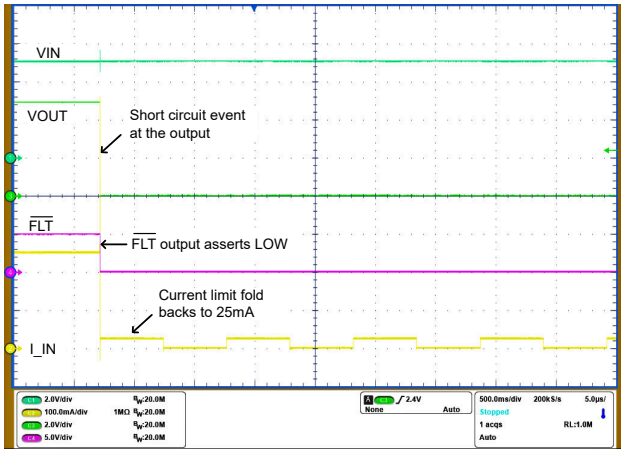

Figure 5. Fold Back Current Response during Short-Circuit Event

At the startup, $\overline{FLT}$ stays LOW till the internal FET of TPS2662 is fully enhanced. This keeps the current limit at fold back value of 25 mA (set by R_5). So, any startup load current >25 mA makes the system fail to startup as shown in Figure 6. To overcome the startup concern, the current limit during startup is enhanced momentarily for a brief period of around 50 ms using a control signal from the system microcontroller (MCU). As illustrated in Figure 3, the switch Q_2 is controlled to increase the current limit during startup to a value corresponding to the resistance R_5 || R_7. The corresponding startup waveform with typical startup load (100 µF || 50 Ω) of other services module (OSM) is shown in Figure 7.

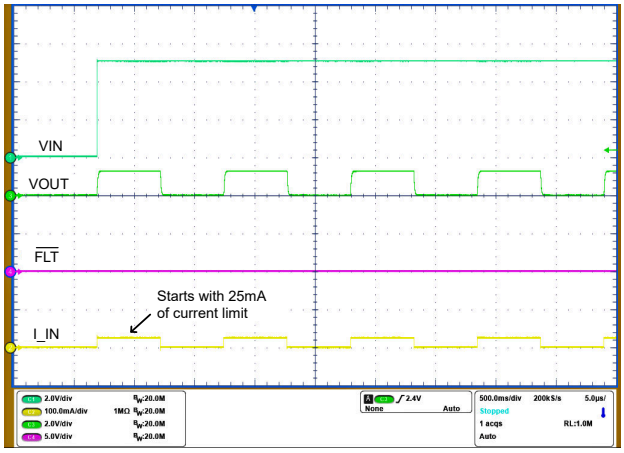

Figure 6. Startup Failure due to Reduced Current Limit with Fold Back Feature

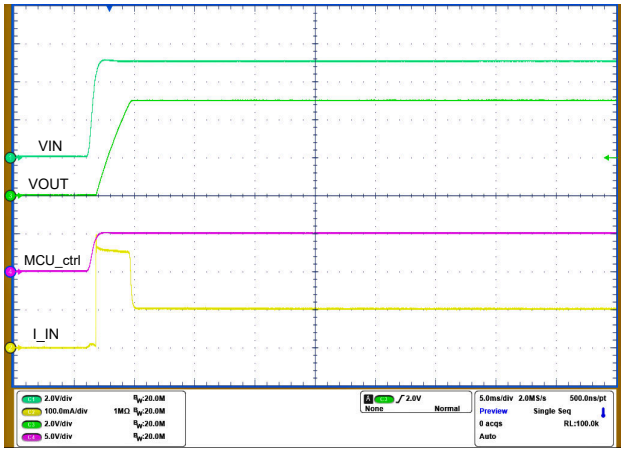

Figure 7. Successful Startup with a Reset Signal from MCU

Conclusion

The port P_1 in smart meter acts as interface with the end consumer and hence demands stringent protection to avoid influencing the metering system as well as protecting the OSM (Other Service Module) devices such as in-house displays. The full suite of protection features from TPS2662 eFuse along with the fold back current limiting approach presented in this article makes it a suitable solution for the protection of P_1 ports in smart meters.

References

1. Texas Instruments, *eFuses in Smart Electricity Meters*, application brief.
2. Texas Instruments, *TPS2662x 60-V, 800-mA Industrial eFuse with Integrated Input and Output Reverse Polarity Protection*, data sheet.
3. Dutch Smart Meter Requirements, *P1 Companion Standard*, 2016.

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